PATENT SPECIFICATION 998,117

DRAWINGS ATTACHED.

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998,117

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Int. Cl.:—G 08 c /C 09 k, G 21.

COMPLETE SPECIFICATION.

Neutron Energy Spectrometers.

We, HITACHI LIMITED, a Corporation organized under the laws of Japan, of No. 12, 2-chome, Marunouchi, Chiyoda-ku, Japan, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to improvements in the structure of neutron energy spectrometers and has for its object to provide a neutron energy spectrometer having an improved detecting efficiency and an improved energy spectrum resolution. Another object of the present invention is to provide a neutron energy spectrometer of the character described which is relatively simple in structure and is capable of undisturbed and accurate measurement involving ideally no measuring errors as caused by the neutron scattering and the local thermal neutron background.

According to the present invention, a neutron energy spectrometer comprises a detector section including a main scintillator formed of liquid helium, He^3, and a photoelectric transducer connected with said main scintillator by way of a light-transmitting pipe, and an output circuit for analysing the output of the detector section such circuit including an anti-coincidence gate circuit.

These and other objects, features and advantages will become apparent from the following detailed description when taken with reference to the accompanying drawings, which illustrate one embodiment of the invention and in which:—

Fig. 1 is a schematic section showing the detector section of a preferred embodiment of the invention; and

Fig. 2 is a schematic diagram showing one form of the entire output circuit of the detector section shown in Fig. 1.

Referring first to Fig. 1, the detector section includes a double type Dewar vessel generally indicated at 1 which is comprised of an inner Dewar vessel 1^1 and an outer Dewar vessel 1^{11} with a cooling medium in the form of a mass of liquid nitrogen 2 filled therebetween. Sealed in the inner Dewar vessel 1^1 is a main scintillator 3, which takes the form of a mass of liquid helium-3 (He^3) according to the invention. A light-transmitting pipe 4 of suitable axial length carries at its one end a transparent disc 5 upon the outer surface of which a fluorescent material which acts as fluorescent material wavelength shifter has been vapor-deposited and is arranged with the disc 5 immersed in the scintillator 3. A photomultiplier 6 and a preamplifier 7 are mounted on the other end of the light-transmitting pipe 4.

An outer scintillator 8 is provided for the detection of neutrons escaping out by elastic scattering from the main scintillator and is conventionally formed of an organic scintillating material containing boron-10 (B^{10}) or cadium (Cd). The outer scintillator 8 is contained in a casing 9 formed of boron steel. Photomultipliers 10, 10^1 and preamplifiers 11, 11^1 are

[*Price 4s. 6d.*]

arranged in sets ab ut the periphery of the casing 9. Though two sets f these units are shown in the drawing, any number of them may be employed as required. A collimator f r the neutron beam to be measured is provided as indicated at 12. A shield case 13 formed of boron steel surrounds the scintillator-containing casing 9 with a shield 14 interposed between the opposing walls of the shield case 13 and the casing 9 for the purpose of shielding neutrons scattering-in from surrounding atmosphere as background.

In Fig. 2, which illustrates one form of the output circuit of the detector shown in Fig. 1, reference numeral 15 denotes a linear pulse amplifier; 16 a pulse-height discriminator circuit; 17 a pulse anti-coincidence gate circuit; 18 a pulse-signal summing circuit; 19, 19^1 linear pulse amplifiers; 20, 20^1 pulse-height discriminator circuits; 21 a pulse coincidence or summing circuit; 22 a multichannel pulse-height analyser; and 23 a data recorder.

In operation, when a neutron beam to be measured is introduced through the collimator 12 (Fig. 1) into the liquid helium-3 scintillator 3 in the Dewar vessel 1, the light produced correspondingly to the neutron energy is introduced through the fluorescent disc (wavelength shifter) 5 and light-transmitting pipe 4 into the photomultiplier 6 to be transformed into electric energy. The electric energy is directed through the preamplifier 7, linear pulse amplifier 15 (Fig. 2), pulse-height discriminator circuit 16 and pulse anti-coincidence gate circuit 17 to the multi-channel pulse-height analyser 22 and further to the data recorder 23, and thus the neutron energy spectrum is analysed and recorded.

The spectrometer according to the present invention, employs liquid helium-3 (He^3) as a main scintillator 3 as described hereinbefore. Such scintillator is high in atomic density and thus presents a large collision cross section to neutrons, providing for a high detection efficiency, as compared with conventional scintillators employing gaseous helium. The use of a liquid helium-3 scintillator is also advantageous in that in the process of preparing liquid helium-3 any impurity atoms which tend to quench the scintillation can be solidified and effectively removed by virtue of the extreme low temperatures involved. In addition, the thermal oscillation-quenching effect is substantially negligible because of the extreme low temperature of the liquid helium. This allows the scintillation output produced by the passage of neutrons through the scintillator to be measured without being quenched to any substantial extent, thus making it possible to analyse the neutron energy spectrum with a highly improved resolution. The mounting of the photomultiplier 6 n the light-transmitting pipe 4, but n t directly n the scintillator 3, is effective to keep the ph tosensitive surface and ther parts of the photomultiplier at a suitably low temperature thereby to reduce the thermal noise of the multiplier improving the signal-to-noise ratio of the detector output. In the event that the neutrons being measured are incident to the main scintillator 3 and are scattered therein, the energy spectrum of the scattered neutrons is not monochromatic but a continuous spectrum, and the scattered neutrons pass out of the main scintillator so that the whole energy of the incident neutrons does not contribute to the scintillation luminescence, and consequently the output of the detector does not correspond to the energy of the incident neutrons. Under these circumstances, scintillation is effected within the main scintillator 3 corresponding to a portion of the neutron energy being measured, but at the same time the scattered neutron gives rise to scintillation in the outer scintillator 8. Accordingly, not only a detector output from the photomultiplier 6 is directed to the pulse anti-coincidence gate circuit 17 but at the same time either of the photomultipliers 10, 10^1 associated with the outer scintillator 8 produces a detector output, which passes through the associated preamplifier 11 or 11^1, pulse-signal summing circuit 18, pulse amplifier 19 or 19^1, pulse-height discriminating circuit 20 or 20^1 and further through pulse coincidence or summing circuit 21 to the pulse anti-coincidence gate circuit 17. Consequently, the gate 17 is closed to cut off the input to the multichannel pulse-height analyser 22 thereby to render the latter inoperative, eliminating the danger of the scattering causing a spectrum error.

The arrangement of the shield case 13 and the shield 14 around the periphery of the detector section is effective to shield substantially all the local thermal neutron background. Even if a background of such an intensity as to penetrate the shielding structure exists, the reduction in the detection efficiency due to the chance anti-coincidence at the gate 17 may be minimized by the selection of only the coincidence signal from the detection output of each of the photomultipliers 10 and 10^1 by the pulse coincidence or summing circuit 21 since the scintillation of the outer scintillator 8, which is associated with said photomultipliers 10 and 10^1, is more frequent than when the scattering takes place as described above.

It will be appreciated from the foregoing that the neutron energy spectrometer of the invention is highly valuable in practical

applications in that it has an improved detecting efficiency and energy spectrum resoluti n and is capable of undisturbed accurate measurement involving little measuring errors as caused by the neutron scattering and the l cal thermal neutron background despite its simple construction.

WHAT WE CLAIM IS:—

1. A neutron energy spectrometer comprising a detector section including a main scintillator formed of liquid helium, He^3, and a photoelectric transducer connected with said main scintillator by way of a light-transmitting pipe and an uter circuit for analysing the output of the detector section such circuit including an anti-coincidence gate circuit.

2. A neutron energy spectrometer substantially as hereinbefore described with reference to and as shown by the accompanying drawings.

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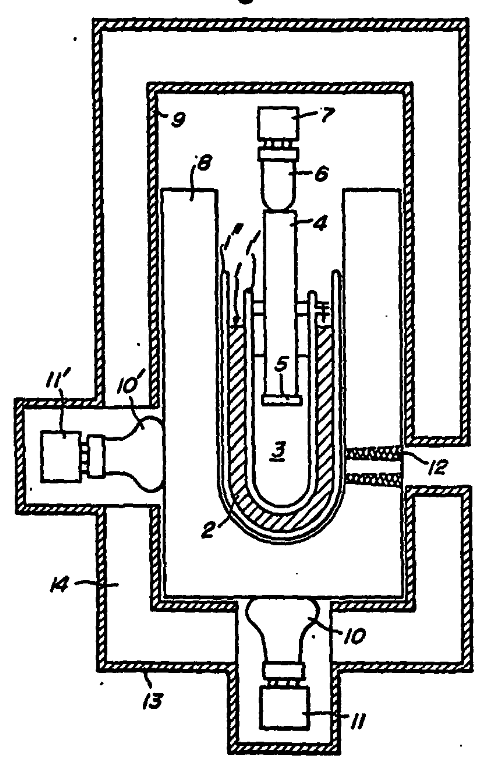
Fig. 1



998117 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheets 1 & 2

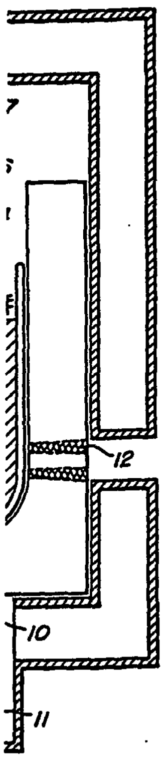


Fig. 2

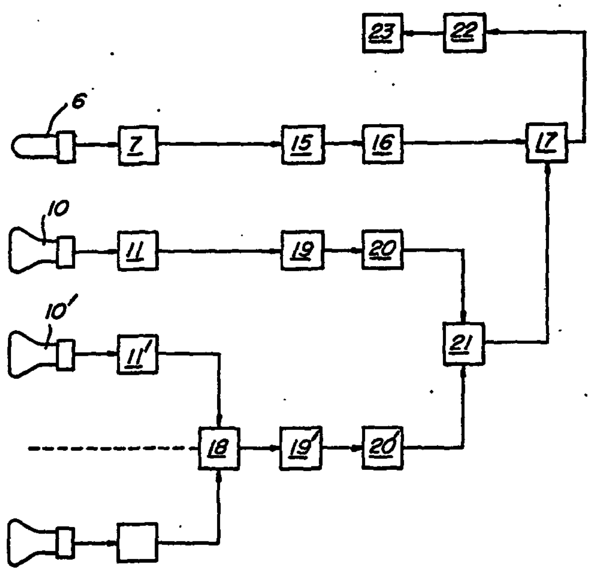


Fig. 1

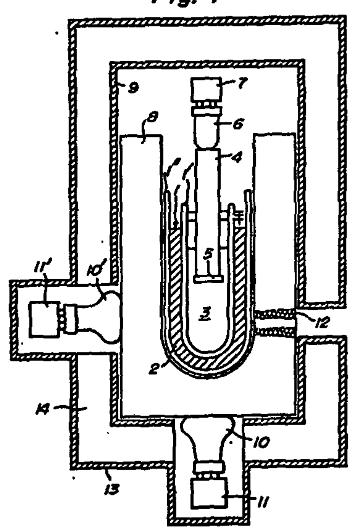

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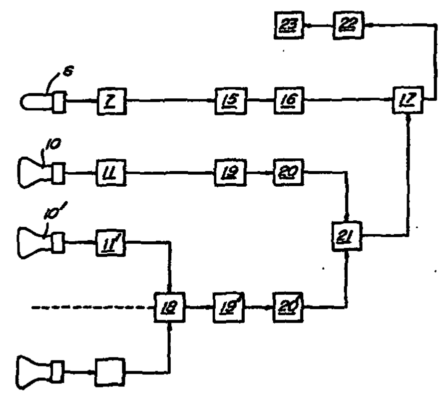
Fig. 2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